Multi-resolution meshes are an important feature of and a major contributor to gains in efficiency and fidelity in modern ESMs. High-quality, highly-nonuniform meshes will be even more important for the seamless incorporation of tidal and estuary systems into ESMs under current development. Other needed improvements are in means for coupling different climate system components and the development of spatially-dependent time stepping strategies. The project addresses these issues that are crucial to the development of improvements in ACME components and in their coupling. The scientific objectives and approaches of the project are embodied in its six overarching objectives.

Develop a 3D grid generation methodology, based on the successfully demonstrated centroidal Voronoi tessellation (CVT) grid generation approach, for the construction of single seamless multi-resolution meshes for ocean, tidal/estuary, and river systems.

Rivers and tidal/estuary systems are usually meshed with much higher resolution than the pelagic ocean. The two grids are usually created separately so that coupling the two types of systems is prone to problems. Based on our success for generating such meshes for regional ocean modeling, we will use our CVT meshing technology to create a single mesh that transitions smoothly from a layered 3D mesh in the pelagic ocean mesh to a finer fully 3D tidal/estuary mesh, and even upstream into rivers. The resulting grids will then be used in the discretization technologies already developed at LANL and implemented in MPAS to produce an accurate model incorporating all these systems, a model that features higher-order accuracy and excellent conservation properties, even in the presence of highly nonuniform grids.

Develop a spatially-dependent time stepping methodology for the efficient solution for coupled ocean and tidal/estuary systems for which spatial discretization involves meshes having a large range of grid sizes.

CFL conditions for explicit time-stepping methods are determined by the finest grid cells, leading to huge inefficiencies. Thus, spatially-dependent time steps are called for. We will develop conservative and accurate spatially-dependent time-stepping schemes for ocean/tidal/estuary systems.

Develop improvement methods for speeding up CVT grid construction.

Current methods in use CVT grid construction are are very robust, but are simplistic and somewhat slow. Thus, especially in view of the highly nonuniform multi-resolution grids we will be constructing for ocean/coastal systems, CVT grid construction needs to be speeded up. We will develop and implement faster methods (e.g., Newton, quasi-Newton, parallel methods) than those now used in MPAS for the construction of highly nonuniform CVT grids.

Develop novel, efficient, and accurate strategies for ESM component coupling in cases where component grids do not match at component interfaces.

Grids used for the various ESMs component are usually determined separately and do not match at component interfaces, leading to difficulties in passing information between components. We will develop a multiphysics coupling technique based on extension operators that has been effective in component coupling in simple settings, even when component grids do not match.

Develop a technology for constructing 3D meshes that match perfectly at interface boundaries and thus facilitate the coupling ESM components.

Alternate to using non-matching grids for ESM components, we will develop an approach that results in meshes that perfectly match at inter-component interfaces, thus facilitating the preservation of conservation properties and accuracy when coupling components. These grids would be fed into the component models from a code generated outside of the component codes.

To have substantial direct impact on ACME ocean/coastal systems and on component coupling within ACME and to develop methodologies that can impact other individual ACME components.

The direct impacts just listed are the primary goals of the project. However, project results will also have impact on other components of the ACME ESM such as:

- a technology for the rapid production of multi-resolution meshes to exploit the multi-scale capabilities of MPAS components
- new ESM component coupler technologies
- extending ESMs to include coastal processes
- a multi-rate time-stepping approach for use in other ESM components.